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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Group decision-making approach for flood vulnerability identification using the fuzzy VIKOR method" *by* G. Lee et al.

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We are very grateful to the reviewer for your valuable comments.
We are writing in response to your comments.

1. Page 1, line 6 et seq.: "fuzzified data" - ugh!

Ans) We mulled over your well-meant advice. However, actually, many other researcher use "fuzzified data" to express "the data is in fuzzified form". We tried to find suitable way to express it then we changed all "fuzzified data" to "data-fuzzification". However we were concerned about that we couldn't

catch your intention.

2. Page 2, lines 18-19: what about uncertainty caused by changing conditions?

Ans) We agree with your point and added following sentence at the introduction

"The second type of uncertainty is caused by the differences among the personal characteristics of each decision maker. The uncertainty caused by the subjective viewpoint of the decision maker means that the decision maker's opinion has been changed by their knowledge. If the decision maker learns more about the conditions such as the possibility of occurrence of a potentially damaging natural event and the change of social-economic vulnerable factor in a given area, their view point would be changed."

3. Page 8: It may well be that in Korea, vulnerability to floods is partly an artefact of fragmentation of responsibility. This has been demonstrated to be the case in some other countries.

Ans) We revised and add following sentence at the introduction

"In South Korea, flood mitigation policy has not controlled by only one organization. The Ministry of Land, Infrastructure, and Transport (MLIT) has developed the comprehensive water resources plan of large dams and rivers to mitigate the flood damage and protect people's properties and damages. The Ministry of Security and Public Administration (MSPA) has taken responsibility of small rivers and their flood damages. Local governments

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have to recover the damaged when flood damage arises. When flood occurs or any flood mitigation projects are determined, conflicts among by MLIT, MSPA and local governments are frequently taken place. Therefore, effective decision making system must be necessary to incorporate different opinions from various stakeholders."

4. Page 9, line 22: I wonder what you did with cultural, institutional and environmental vulnerability? If you left them out, you should at least state that this is an incomplete analysis of the problem.

Ans) Through our previous study, we adopted the indicator to assess flood vulnerability including social, economic and hydrologic response against flood. We guess your suggestion about cultural, institutional and environmental vulnerability are parts of response against flood.
In Korea, government is proactive about the most activities against flood. The voluntary activities of local residents are very unusual and not continuous. Therefore five criteria on the response were adopted after Delphi procedure survey of experts.
(1) Number of flood and disaster prevention institutions and (2) number of government officials for flood and disaster mitigation in social factors of vulnerability, (3) Annual recovery and preparation costs for floods and disasters in Economic factors of vulnerability, and (4) Number of flood mitigation infrastructures and (5) River improvement ratio in Hydrologic factors of vulnerability are considered the response criteria.
And we added following sentence as chapter 4.

"Since identifying the appropriate criteria is very crucial in vulnerability study, this study approached the systematic hierarchy structure for sustainability. The criteria were divided into three characteristic groups: social,

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economic, and hydrologic components. The intent was to provide supporting results for appropriate policies by forming groups of similar properties. The research staff established a draft criteria list based on the three components and distributed it to the decision-making groups during the first-round survey of the Delphi procedure. For the flood vulnerability assessment, the participants completed the survey in which they expressed their opinions regarding the importance of factors. Their responses were analyzed to develop 24 criteria, as shown in Table 1."

5. (1) Table 1 does not seem to have sorted out the distinction between hazard and vulnerability, or the interaction between the two. (2) Why is there no ranking of vulnerability factors? This seems to be a classic inductive analysis, with all the defects of that technique.

Ans) (1) In previous study (Integrated multi-criteria flood vulnerability approach using fuzzy TOPSIS and Delphi technique, 2013), we tried to explain the distinction between hazard and vulnerability using the pressure-state-impact-response (PSIR) framework, which excludes the driving force of DPSIR.
We added following paragraph.

"This study had been considered critical social, economic and environmental vulnerability factors based on PSIR (Pressure-State-Impact-Response) framework which excludes the driving force of DPSIR (Driving force--Pressure-State-Impact-Response) framework. It is the reason why the indicators of D (Driving force) are widely applicable in the whole study area, and thus its value of each alternative are not distinguishable. Each attribute of PSIR is briefly described below. Pressure leads to environmental awareness of flood risk. In turn these pressures affect the state of the

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environment, which refers to various flood-related circumstances and their subsequent ability to support the demands placed on. Changes in state may have an impact on human health, ecosystems, biodiversity, amenity value and financial value. The impacts may be expressed in terms of the level of harm caused by the flood. The response demonstrates the efforts by society to solve the problems identified by the assessed impacts, such as policy measures and planning actions."

(2) We assumed that the ranking of vulnerability factors could be estimated the weights of criteria. The weight sets were constructed by decision makers in our procedure. Thus we had 44 sets of the ranking of vulnerability factors. We considered your suggestion and added the summerty of weighing in Table 1.

This paper seems to be about numerical analysis for the sake of numerical analysis. Vulnerability is a process, not a set of numbers. To adopt a blank, unselective inductive approach is hardly to illuminate the meaning of variations in vulnerability. If the phenomenon is to be reduced, it must be understood. Merely coming up with sets of numbers and percentages does not help that process, and it lays the authors of the study open to the accusation "garbage in, garbage out". I am not impressed by the use of experts.
They seem to have contributed remarkably little to the understanding of the phenomenon. Hence, the authors have refined the techniques of comparing and ranking and assimilating large, heterogeneous data bases, but the paper has remarkably little to say about vulnerability to floods.

Ans) We completely accept your view.
We try to develop the assessment procedure of flood vulnerability that can be applied to policy in Korea. We studied the approach of flood

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vulnerability assessment in previous research. During the study we found that the weights set determined by averaged opinions of decision makers can be distorted. Thus we had an idea that can be reduce the difference using numerical way. This study is part of a process of making a credible assessment result for flood vulnerability management. We added how we constructed flood vulnerability factors at chapter 2.2.

"Under this PSIR framework, the flood vulnerability formula can be defined as follows:
$FVI = \times \mathbf{w}_p + SVul \times \mathbf{w}_s + IVul \times \mathbf{w}_I + RVul \times \mathbf{w}_R$
Where PVul, SVul, IVul and RVul are the values of pressure, state, impact and response components which are the aggregated values of each criterion combined with the weights."

However there still remains a few subject to be studied as pointed out your view. Particularly to construct flood vulnerability factors is most important problem. Then we have been studying composing the proper factors related regional characteristics and capability in next research. Furthermore, the relationship between the flood vulnerability developed in this study and real flood damages should be investigated in the future. Then the future flood damage can be approached by flood vulnerability coupling with climate change scenarios.

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Table 1 Criteria for flood vulnerability and summery of weighting

Category	Criteria (measure)	VL	L	ML	M	MH	H	VH
Social factors		0	6	26	7	5	0	0
Pressure		2	12	9	6	3	10	2
	Population growth ratio (%)	0	6	13	3	19	3	0
	Population (number)	2	4	0	9	15	7	7
State		0	12	11	10	9	2	0
	Residential and industrial area ratio (%),	4	4	8	9	18	1	0
	Population density (man/1km^2)	0	3	8	12	0	17	4
	Number of social overhead capital, cultural properties and natural monuments (number)	6	10	8	5	12	0	3
Impact		0	7	4	12	13	8	0
	Annual casualties and sufferers due to floods and disasters (number/year)	1	0	0	3	16	16	8
Response		5	14	9	8	6	2	0
	Number of flood and disaster prevention institutions (number/year)	2	3	6	13	9	8	3
	Number of government officials for flood and disaster mitigation (number)	1	3	9	8	12	7	4
Economic factors		0	2	14	15	8	5	0
Pressure		8	10	10	6	8	2	0
	Gross regional domestic product(KRW)	0	1	15	14	9	4	1
State		2	2	11	15	7	2	5
	Urban area ratio (%)	1	2	8	13	7	10	3
	Self-reliance ratio of finance (%)	0	8	12	10	11	1	2
	Property value(KRW)	5	3	9	3	10	11	3
Impact		2	6	6	7	5	16	2
	Annual flood damage (number/year)	1	0	0	0	5	24	14
Response		0	11	12	6	7	6	2
	Annual recovery and preparation costs for floods and disasters (KRW/year)	0	1	5	13	15	7	3
Environmental factor		0	0	2	0	12	4	26
Pressure		3	4	13	9	6	7	2
	Increased ratio of daily maximum precipitation (%)	0	7	13	1	9	11	3
	Increased ratio of 1-hr rainfall intensity (%)	1	0	9	14	4	5	11
	Increased ratio of summer rainfall (%)	4	9	9	11	4	7	0
	Watershed slope (deg)	8	18	4	9	5	0	0
State		0	8	6	12	9	5	4
	Peak flow of the 200-yr floods	0	2	17	8	5	9	3
	River stage of the 200-yr floods	0	6	12	6	7	7	6
Impact		0	6	4	12	11	9	2
	Annual number of floods (number/year)	0	1	4	9	17	10	3
	Flood inundation area (km^2)	1	0	0	13	11	12	7
Response		2	12	11	9	3	7	0
	Number of flood mitigation infrastructures (number)	2	7	9	12	8	6	0
	River improvement ratio (%)	0	5	8	12	10	5	4

Fig. 1.

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